Analysis of Indoor Air Constituents Following Use of Ploom® Heated Tobacco Products Compared to Cigarette Smoking

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ABSTRACT

The Ploom® System (a heated tobacco device that uses Marlboro® heated tobacco sticks [HTS]) generates an aerosol with overall substantially lower harmful and potentially harmful constituents (HPHCs) compared to combustible cigarette smoke, offering a potentially reduced risk alternative for adults who smoke. It is also expected that bystanders would be exposed to substantially lower levels of HPHCs relative to cigarette smoking. We measured 23 analytes including HPHCs and other chemicals commonly analyzed in environmental tobacco smoke studies, in an environmental chamber (EC). The indoor air samples were collected over a 2-hour period. Four participants used Ploom® System, smoked their usual brand menthol or tobacco combustible cigarette (UBCC), or used no products (Background), with each session repeated three times. To maximize detection of analytes, the EC was not supplied with air exchanges during the entire test and the air sampling period, representing a worst-case scenario. The Ploom® System (with tobacco or menthol HTS) was compared to participants' UBCC. Concentrations of most analytes from the Ploom® System were not statistically significantly elevated compared to Background. Except for glycerol and o-cresol, most background-corrected analyte concentrations after Ploom® System use were statistically significantly lower compared to the corresponding UBCC. Combined data (Ploom® System and UBCC) showed all analytes, except glycerol and o-cresol, were significantly reduced in the Ploom System use by 83 ~100%. These findings demonstrate that aerosol from the Ploom® System significantly reduces bystander exposure to the measured HPHCs compared to combustible cigarettes.

INTRODUCTION & AIMS

Background: Environmental tobacco smoke (ETS), popularly referred to as second-hand smoke, is the side-stream emissions released from a burning tobacco product and the smoke exhaled by the user. Public health officials have concluded that secondhand smoke from cigarettes causes disease.[1,2] The Ploom® System (a heated tobacco device that uses Marlboro® heated tobacco sticks, HTS) generates an aerosol with overall substantially lower levels of harmful and potentially harmful constituents (HPHCs) compared to combustible cigarettes, offering a potentially reduced harm to users as well as bystanders.

Purpose: The purpose of this study was to quantify and compare the concentrations of selected harmful and potentially harmful constituents (HPHCs) and respirable suspended particles (RSPs) in indoor air resulted from the use of menthol- and tobacco-flavored Ploom® heated tobacco system (HTS) and participants' usual brand combustible cigarette (UBCC), under controlled conditions within an environmental chamber (EC).

METHODS

Healthy adults 22 years or older who had smoked at least 5 combustible cigarettes per day for at least the past 12 months, with urinary cotinine ≥ 200 ng/mL and exhaled carbon monoxide (CO) ≥ 10 ppm, were recruited for this open-label, single-center study. Participants were assigned to either the *tobacco-flavored* or *menthol-flavored* variant of Ploom® HTS, based on the flavor of their UBCC.

The environmental chamber (EC) used in this study was a walk-in room (size: 9.3 m^2, volume: 28.3 m^3) with no ventilation during product use and air sampling (Figure 1). Each test session involved four participants entering the EC, resting for 10 minutes, and then using one stick of their assigned Ploom® HTS products over a 10-minute period before exiting. In a separate session under identical conditions, four participants each smoked one stick of their UBCC for 10 minutes.

On each test day, background sessions were conducted in which participants entered the EC for 20 minutes without using any product. These background measurements were used to correct for contributions from participants and ambient air. CO and total volatile compound (TVOC) levels were continuously monitored in real time. Time-weighted average (TWA) sampling of indoor air constituents—including selected HPHCs, RSPs, and other chemical compounds (Table 1)—was conducted for 2 hours immediately following participants' exiting the EC. Each condition was repeated 3 times with different participants per group. Comparisons were made between the two Ploom® HTS variants and the two UBCC variants, as well as between the combined Ploom® HTS products (menthol and tobacco) and combined UBCC (menthol and non-menthol).

Figure 1. Environment Chamber

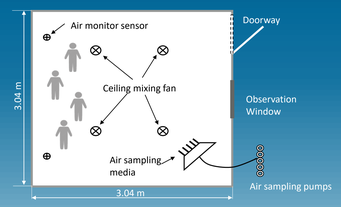


Table 1. Constituents Measured

Constituent	Classification
Carbon Monoxide (CO)	RDT
TVOC	Volatile compounds
Respirable Suspended Particles (RSP <2.5μm)	Impact respiratory and cardiovascular
Ultraviolet Particulate Matter (UVPM)	Impact respiratory and cardiovascular
Florescence Particulate Matter (FPM)	Impact respiratory and cardiovascular
Solanesol	ETS aerosol Tracer
Nicotine	RDT, AD
3-ethenylpyridine (3-EP)	A pyrolysis product of nicotine
Ammonia	RT
Formaldehyde	CA, RT
Acetaldehyde	CA
Benzene	CA, CT, RDT
ortho-Cresol	CA, RT
meta- and para-Cresol	CA, RT
Ethylbenzene	CA
Glycerol	Commonly tested in ETS
Phenol	RT, CT
Pyridine	Respiratory irritation
Pyrrole	Respiratory irritation
Styrene	CA
Toluene	RT, RDT
ortho-Xylene	Hazardous effects on respiratory, central nervous, cardiovascular and renal systems
meta- and para-Xylene	Hazardous effects on respiratory, central nervous, cardiovascular and renal systems

CA=Carcinogen; RT=Respiratory Toxicant; CT=Cardiovascular Toxicant, RDT=Reproductive or Developmental Toxicant, AD=Addictive

Table 2. Participant Demographics

Characteristic	Non-Menthol Group (N=17)	Menthol Group (N=15)	Overall (N=32)
Age (years) Mean (SD)	36.7 (8.98)	43.2 (8.06)	39.8 (9.05)
Ethnicity, n (%)			
Hispanic or Latino	0 (0.0)	0 (0.0)	0 (0.0)
Not Hispanic or Latino	17 (100.0)	15 (100.0)	32 (100.0)
Race, n (%)			
Black or African American	13 (76.5)	15 (100.0)	28 (87.5)
White	4 (23.5)	0 (0.0)	4 (12.5)
Sex, n (%)			
Male	9 (52.9)	6 (40.0)	15 (46.9)
Female	8 (47.1)	9 (60.0)	17 (53.1)
Cigarettes smoked per day	9.5 (3.89)	10.4 (5.67)	9.9 (4.75)

Results

Table 3. Background-Corrected EC Air Constituent Concentrations

a) Individual Products

Constituents (μg/m³)	Non-Menthol UBCC Mean (SD)	Menthol UBCC Mean (SD)	Tobacco-Ploom® HTS Mean (SD) % Reduction	Menthol-Ploom® HTS Mean (SD) % Reduction
RSP	2392.51 (233.754)[a]	1969.04 (363.588)[a]	39.34 (6.648)[a,b] 98%	79.81 (22.265)[a,b] 96%
UVPM	314.94 (31.683)	243.63 (48.815)[a]	0.48 (0.410)[b] 100%	0.80 (2.196)[b] 100%
FPM	113.97 (5.306)[a]	83.30 (17.834)[a]	0.15 (0.140)[b] 100%	0.04 (0.066)[b] 100%
Solanesol	99.39 (12.065)[a]	79.04 (14.264)	0.22 (0.210)[b] 100%	0.66 (0.398)[b] 99%
Nicotine	43.68 (6.426)[a]	31.72 (7.996)[a]	1.12 (0.769)[b] 97%	0.92 (0.442)[b] 97%
3-Ethenylpyridine	45.07 (10.013)[a]	43.03 (4.935)[a]	0.00 (0.001)[b] 100%	-0.00 (0.005)[b] 100%
Ammonia	444.82 (48.096)[a]	417.30 (26.203)[a]	0.08 (0.062)[b] 100%	-0.055 (0.222)[b] 100%
Formaldehyde	125.78 (96.360)[a]	201.04 (20.697)[a]	5.28 (1.492)[a] 96%	2.28 (2.054)[b] 99%
Acetaldehyde	285.92 (164.541)[a]	320.05 (23.233)[a]	16.76 (1.199)[a] 94%	8.92 (8.424)[b] 97%
Benzene	25.47 (4.685)[a]	20.38 (3.070)[a]	0.00 (0.002)[b] 100%	-0.00 (0.013)[b] 100%
ortho-cresol	-0.00 (0.001)	0.04 (0.268)	0.00 (0.000) NC	0.07 (0.061) NC
meta- and *para*-cresol	0.78 (0.443)[a]	0.65 (0.291)[a]	0.00 (0.000)[b] 100%	0.11 (0.133)[b] 83%
Ethylbenzene	11.01 (3.366)[a]	10.06 (0.632)[a]	-0.14 (0.277)[b] 100%	-0.02 (0.030)[b] 100%
Glycerol	-0.00 (0.021)	0.11 (0.032)	3.25 (3.263) NC	-0.08 (0.250) NC
Phenol	3.82 (2.035)[a]	3.00 (1.633)[a]	0.30 (0.432)[b] 92%	0.35 (0.140)[a,b] 88%
Pyridine	26.51 (8.406)[a]	27.75 (2.115)[a]	0.28 (0.292)[b] 99%	0.37 (0.093)[a,b] 99%
Pyrrole	31.36 (2.506)[a]	32.90 (2.195)[a]	0.08 (0.150)[b] 100%	0.24 (0.023)[a,b] 99%
Styrene	16.32 (2.310)[a]	15.48 (1.168)[a]	0.00 (0.137)[b] 100%	-0.00 (0.006)[b] 100%
Toluene	113.64 (18.915)[a]	78.25 (3.402)[a]	0.77 (1.068)[b] 99%	0.06 (0.295)[b] 100%
ortho-xylene	6.57 (3.883)	6.62 (0.500)[a]	0.01 (0.025) 100%	-0.01 (0.047)[b] 100%
meta and *para*-xylene	46.98 (10.947)[a]	33.13 (2.233)[a]	-1.15 (2.448)[b] 100%	0.41 (0.756)[b] 99%
CO (ppm)[c]	8.20 (0.849)[a]	8.60 (0.346)[a]	-0.00 (0.100)[b] 100%	-0.10 (0.100)[b]100%
$TVOC_{-direct}$[c]	2809.5 (78.49)[a]	2330.0 (423.36)[a]	60.0 (9.85)[b] 98%	70.0 (31.61)[b] 97%

b) Combined Products

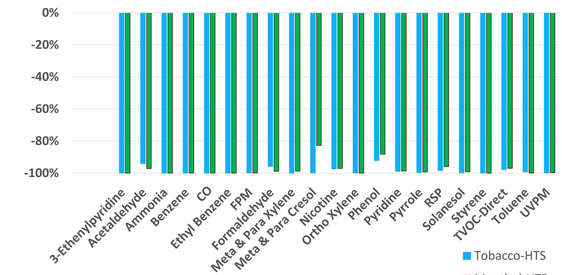
Constituents (μg/m³)	UBCC Mean (SD)	Ploom® HTS Mean (SD), % Reduction
RSP	218.78 (358.516)[a]	59.57 (26.596)[a,b], 97%
UVPM	279.28 (53.669)[a]	0.64 (1.424)[b], 100%
FPM	98.64 (20.510)[a]	0.091 (0.114)[b], 100%
Solanesol	89.22 (16.243)[a]	0.44 (0.373)[a,b], 100%
Nicotine	37.70 (9.221)[a]	1.02 (0.571)[a,b], 97%
3-Ethenylpyridine	44.05 (7.148)[a]	0.00 (0.004)[b], 100%
Ammonia	431.06 (37.776)[a]	0.02 (0.162)[b], 100%
Formaldehyde	163.41 (74.731)[a]	3.78 (2.299)[a,b], 98%
Acetaldehyde	302.99 (106.747)[a]	12.85 (6.890)[a,b], 96%
Benzene	22.93 (4.507)[a]	-0.00 (0.008)[b], 100%
ortho-cresol	0.02 (0.171)	0.03 (0.053) , NC
meta- and *para*-cresol	0.72 (0.343)[a]	0.06 (0.104)[b], 92%
Ethylbenzene	10.54 (2.229)[a]	-0.08 (0.188)[b], 100%
Glycerol	0.05 (0.063)	1.58 (2.760), NC
Phenol	3.41 (1.711)[a]	0.33 (0.289)[b], 90%
Pyridine	27.13 (5.524)[a]	0.33 (0.200)[b], 99%
Pyrrole	32.13 (2.269)[a]	0.16 (0.126)[b], 99%
Styrene	15.90 (1.701)[a]	-0.00 (0.087)[b], 100%
Toluene	95.94 (22.879)[a]	0.42 (0.802)[b], 100%
ortho-xylene	6.59 (2.476)[a]	-0.00 (0.035)[b], 100%
meta and *para*-xylene	40.05 (10.368)[a]	-0.37 (1.831)[b], 100%
CO (ppm)[c]	8.44 (0.537)[a]	-0.05 (0.105)[b], 100%
$TVOC_{-direct}$[c]	2521.8 (400.17)[a]	65.0 (21.64)[b], 97%

% reduction = (1- HTP/Combustible Cigarette) x 100%; ." UBCC=Usual Brand Combustible Cigarette; RSP= Respirable Suspended Particles; FPM= Florescence Particulate Matter; UVPM= Ultraviolet Particulate Matter; TVOC=Total Volatile Organic Compound; NC = not calculated for glycerol and *ortho*-cresol because none of them were statistically significantly higher than the Background for all the Test and Reference products.

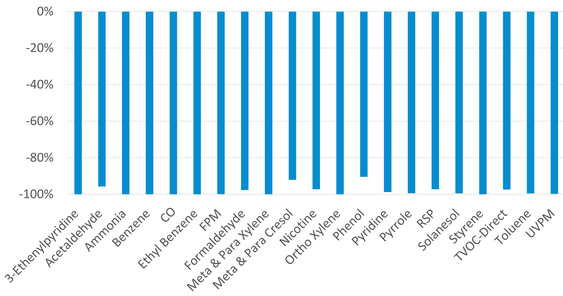
[a] $p < 0.05$ vs Background; [b] $p < 0.05$ vs UBCC; [c] Maximum value from the real time monitoring

Figure 2. Percent Reduction in Indoor Air Constituents of the Ploom® HTS Compared to UBCC

a) Tobacco and Menthol Ploom® HTS Products Compared to Non-Menthol & Menthol UBCCs



b) Combined Ploom® HTS Products Compared to combined UBCCs



SUMMARY

- In both the Menthol and Non-Menthol groups, the majority of measured indoor air constituents following use of the Ploom® HTS — after background adjustment — were substantially and statistically significantly lower compared to levels observed after smoking UBCCs.
- Reductions in constituent levels following Ploom® HTS use ranged from 83% to 100% relative to UBCCs.
- Of the 23 constituents measured, 17 showed no statistically significant difference from background levels after Ploom® HTS use, except for acetaldehyde, formaldehyde, and RSP in the *tobacco-flavored* variant, and phenol, pyridine, pyrrole, and RSP in the *menthol-flavored* variant.
- Combined analysis of pooled data from both Ploom® HTS variants versus pooled data from both UBCC variants revealed statistically significant reductions in all constituents except glycerol and ortho-cresol, with reductions ranging from 90% to 100%.

CONCLUSIONS

- The results of this study demonstrate that indoor air levels of selected harmful and potentially harmful constituents (HPHCs) following use of the Ploom® System were substantially lower than those observed after smoking combustible cigarettes and were generally comparable to background air levels.
- These findings suggest that the Ploom® System will significantly lower bystander exposure to harmful chemicals compared to combustible cigarette use.

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